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Evolution of the Lunar Receiving Laboratory to Astromaterial Sample Curation Facility: Technical Tensions Between Containment and Cleanliness, Between Particulate and Organic Cleanliness





- Setting the scene and timeline
- General comparison of purpose, “customers”, and who defined requirements
- Lunar Receiving Laboratory (LRL)
 - Description and lab operation
 - Debates over technical aspects of containment vs cleanliness
- Lunar Curatorial Facility
 - Description and lab operation
 - Focus on control of materials of construction and equipment
- Added astromaterial collection laboratories
 - Retrofitting lab spaces
 - Approaches to particulate and organic cleanliness

Setting the scene and timeline



The Lunar Receiving Laboratory and the Lunar Curation Facility both were:

- Major facilities
- Defined purpose
- Extended planning and oversight/advisory committees

LUNAR RECEIVING LABORATORY

PURPOSE: Distribution of samples to the scientific community, perform time-critical sample measurements, permanently store under vacuum a portion of each sample, and quarantine testing of samples, spacecraft and astronauts

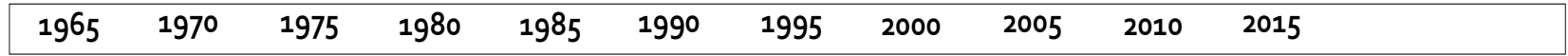
CUSTOMERS: in-house biohazard testers, planetary science researchers

WHO DEFINED REQUIREMENTS FOR FACILITY: US Public Health Service (plus others, making up the Interagency Committee on Back Contamination), Manned Spacecraft Center management (with input from geoscience)

LUNAR CURATION FACILITY

PURPOSE: Keep the samples pure, preserve accurate historical information about the samples, examine and classify samples, publish information about newly-available samples, and prepare and distribute samples for research and education

CUSTOMERS: Planetary science researchers, educators
WHO DEFINED REQUIREMENTS FOR FACILITY: Planetary science researchers



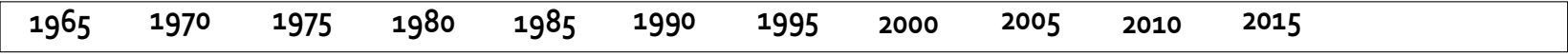
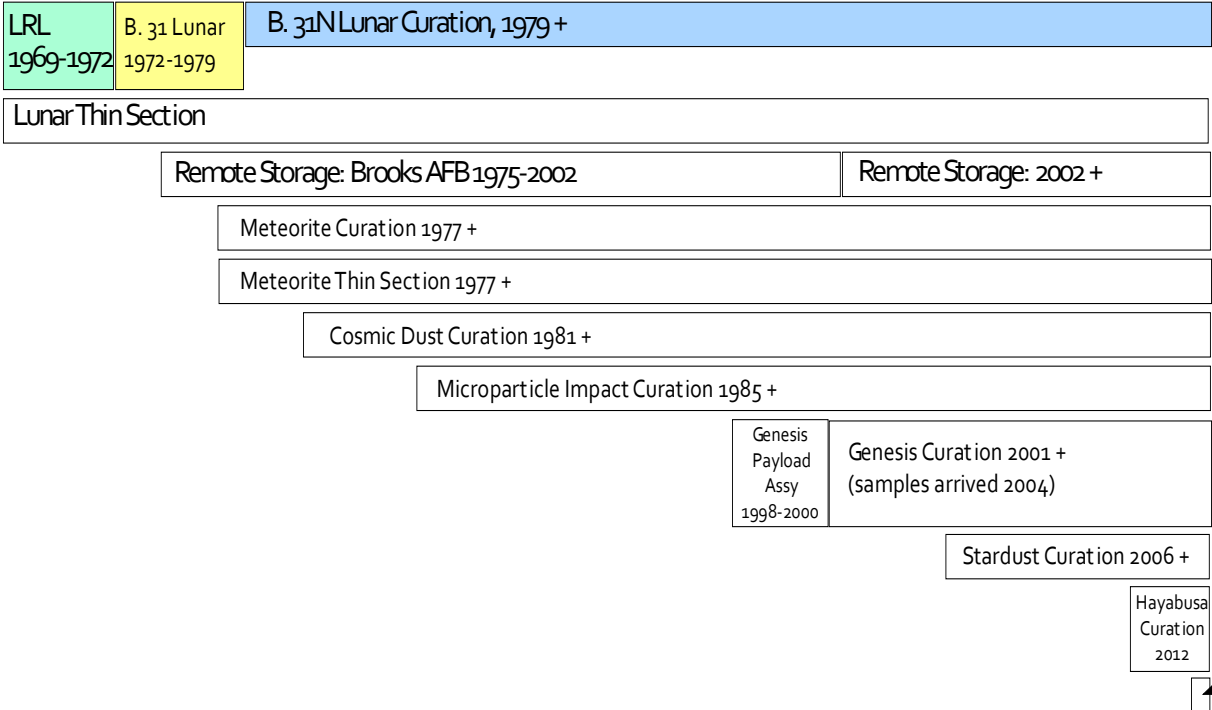
New Facility Planning, Construction, Check-out

LRL
1964-1966

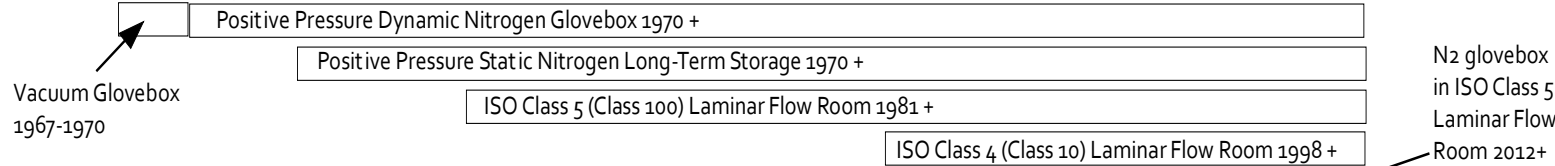
B. 31N
1972-1979

Retro-fit facilities: B. 31 Lunar Meteorite Cosmic Dust Microparticle Impact Genesis Stardust Hayabusa O-REx

Sample Handling & Curation Facility Operation



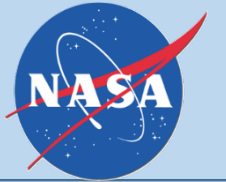
Sample Handling Environment



Common Infrastructure Support



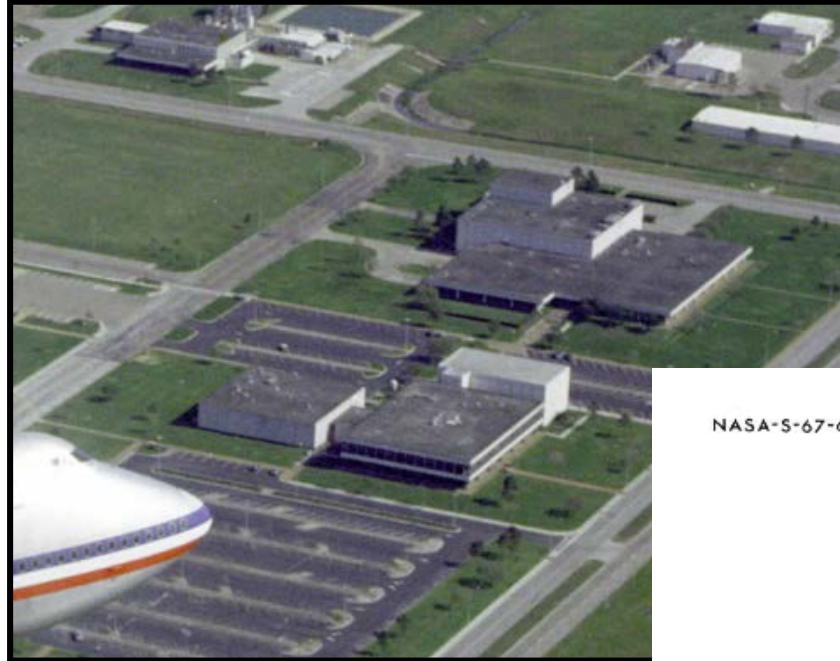
LRL DESCRIPTION



8000 m², \$24M (most expensive vacuum system, low level radiation counting)

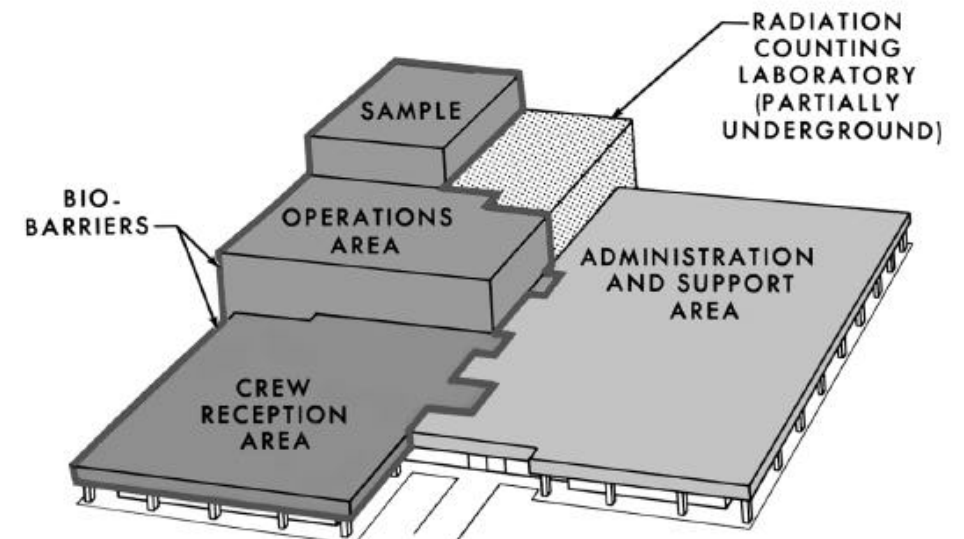
100 NASA civil servants and visiting scientists, 200 technicians working 3 shifts

Outside science community recruited to participate in 1) scientific oversight of sample curation and allocation (Lunar Sample analysis Planning Team, LSAPT), and 2) Preliminary Examination Team (PET)

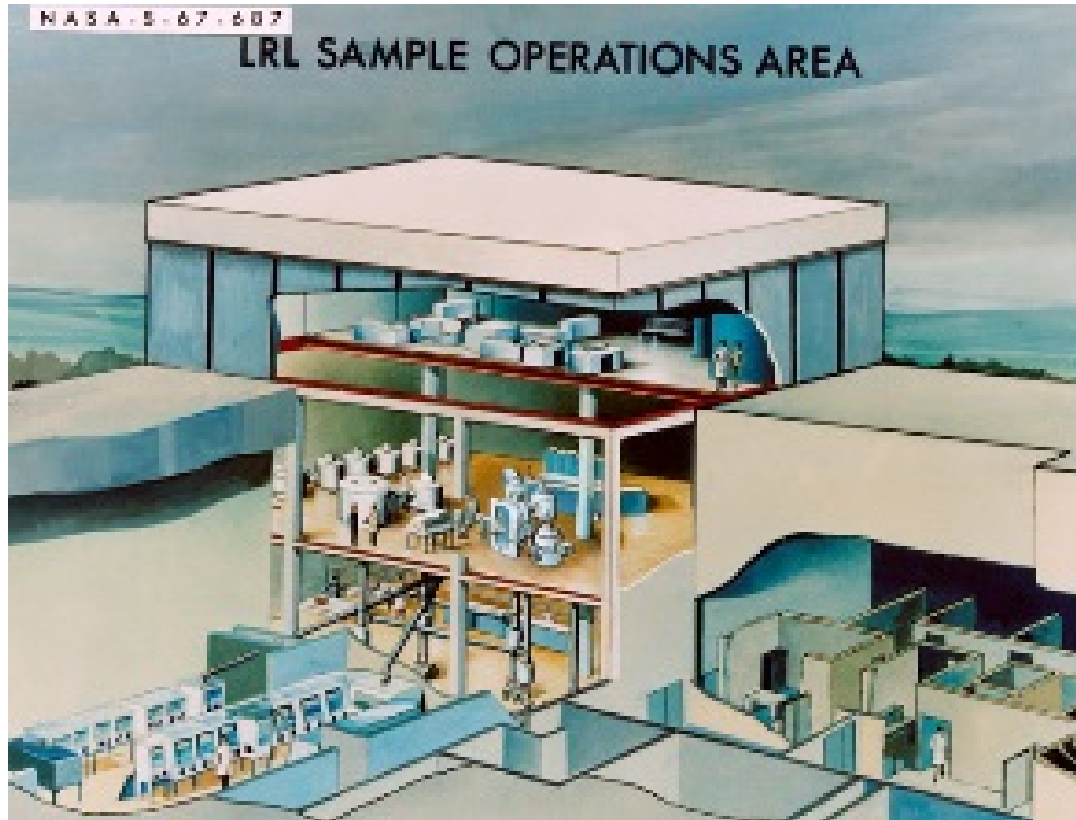
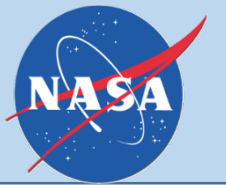


NASA-S-67-696

LRL FUNCTIONAL AREAS

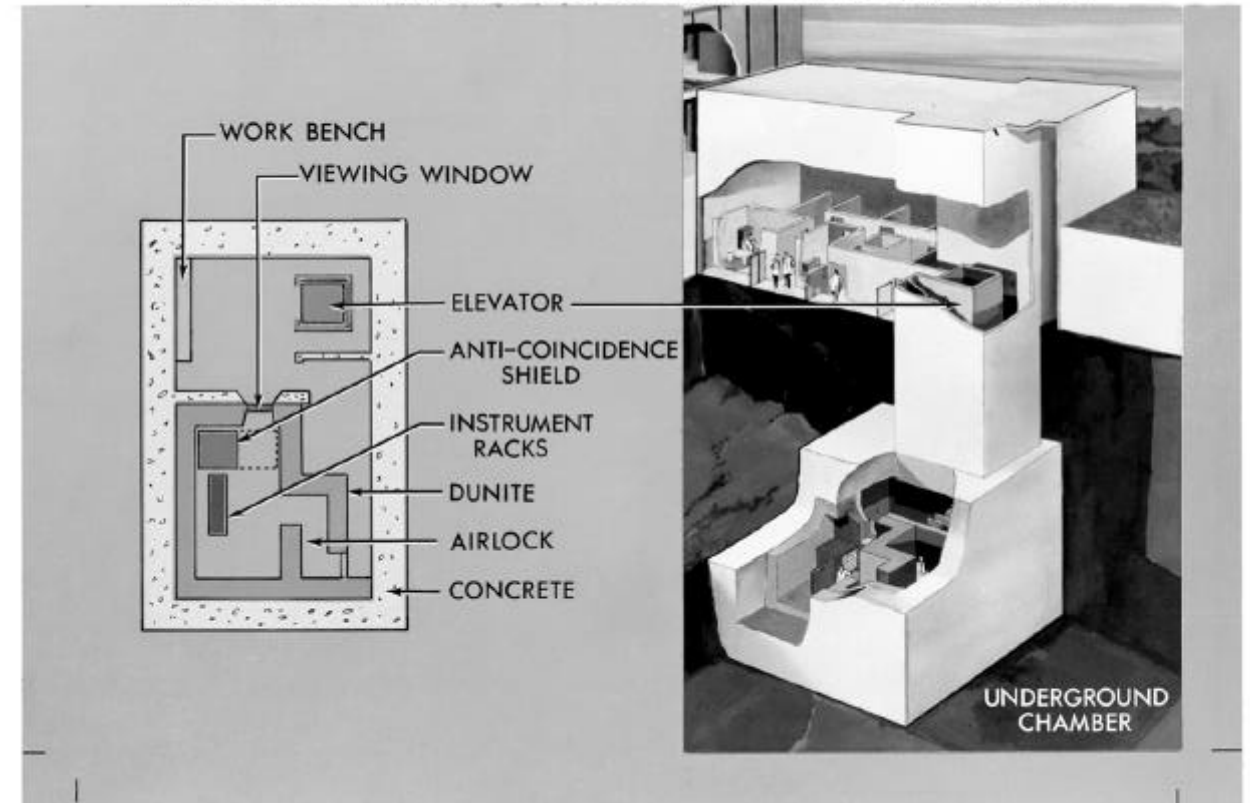


LRL DESCRIPTION

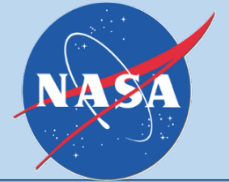


NASA-S-67-689

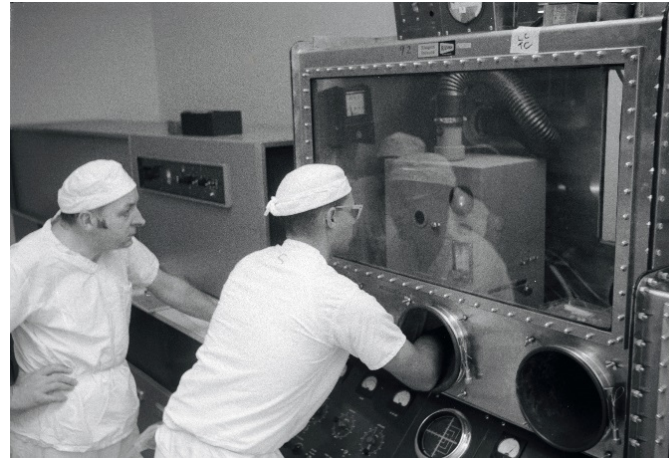
LRL RADIATION COUNTING LABORATORY



LRL DESCRIPTION

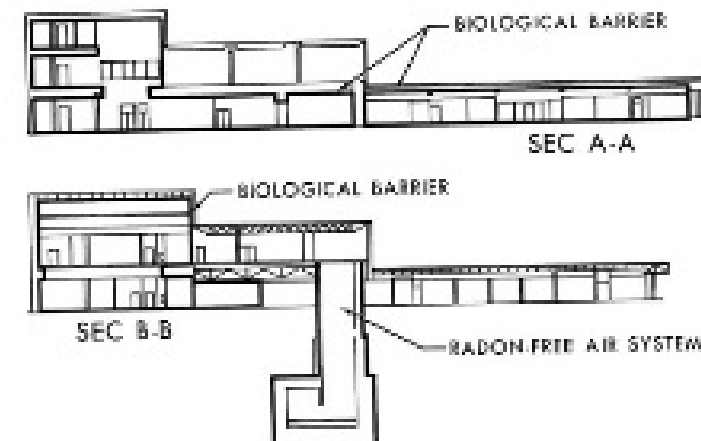


Physically, the main divisions of the LRL behind the biological barrier were the samples operations areas and the Crew Reception Area, consisting of crew living areas and medical examination facilities. The sample operations areas included the vacuum sample handling system, laboratories for quarantine testing, laboratories for analysis of samples and the subsurface facility for counting low levels of radiation. Complex plumbing spanning 3 floors was required to operate the sophisticated vacuum system constructed for lunar sample handling

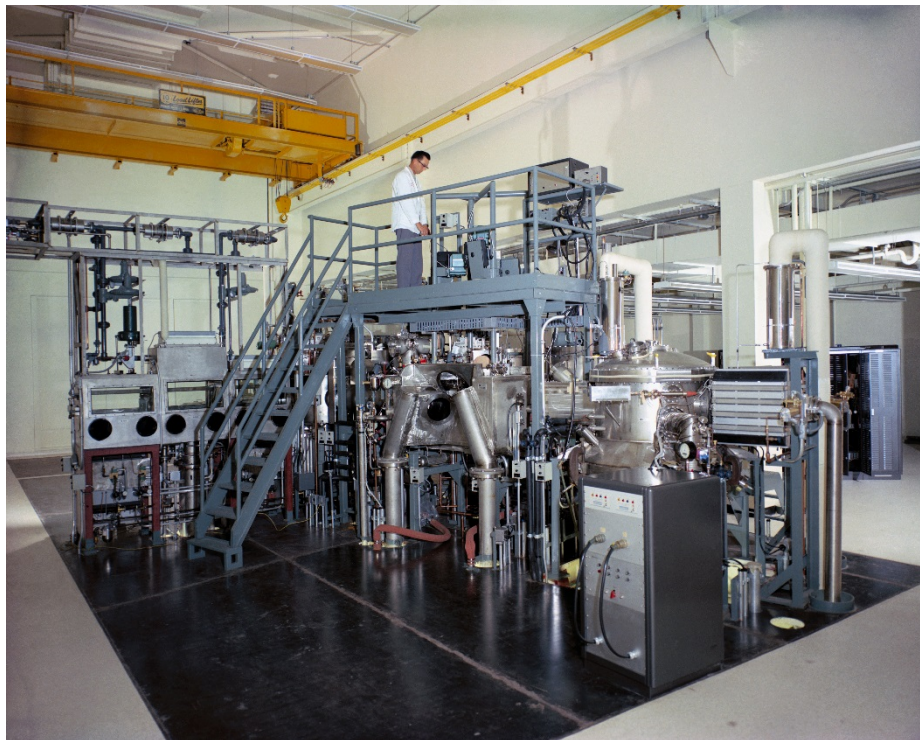
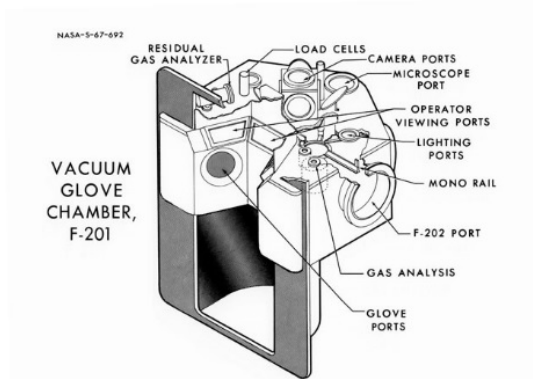
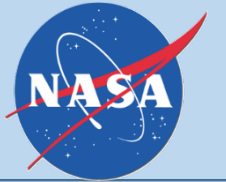


NASA S-87-3137

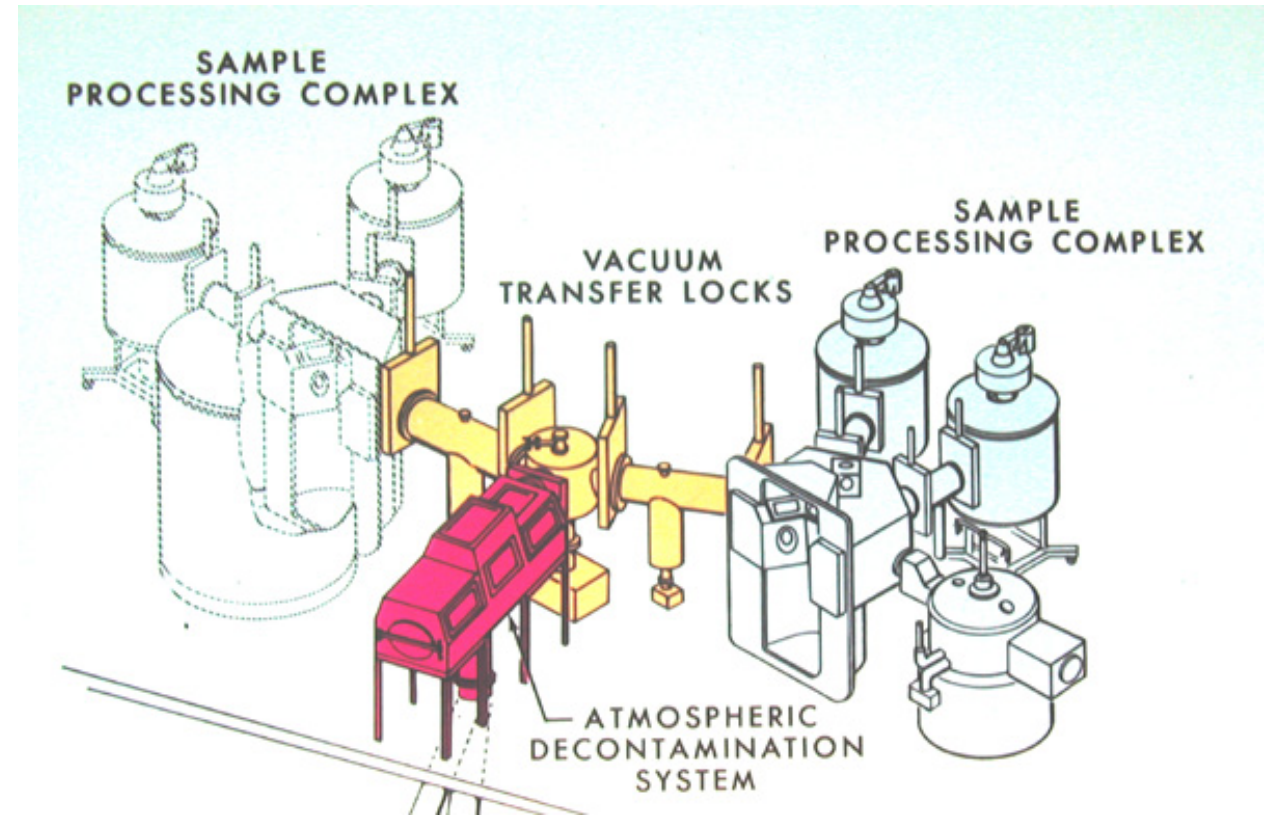
LRL BUILDING SECTIONS



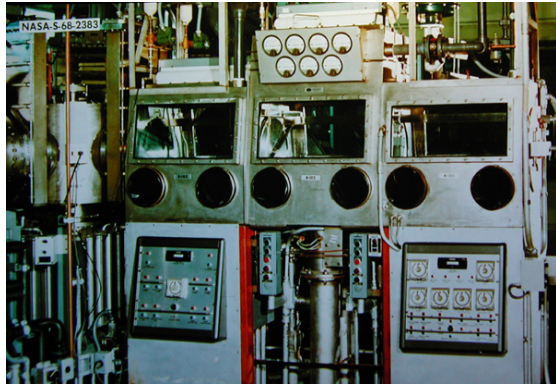
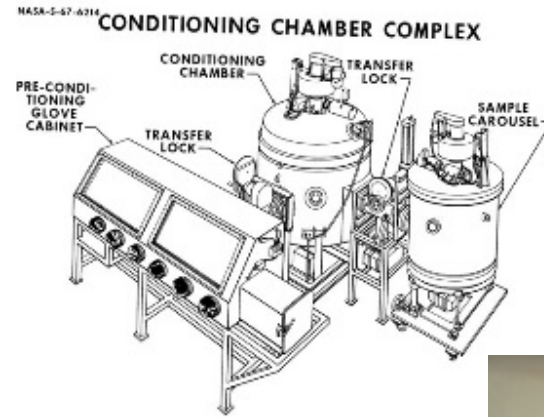
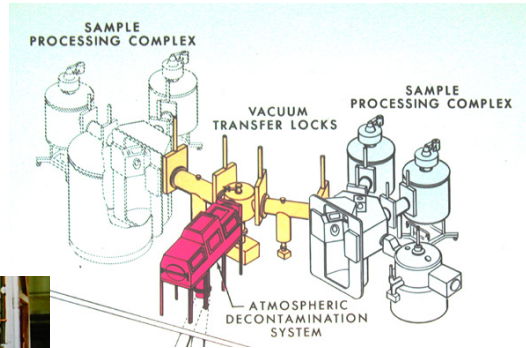
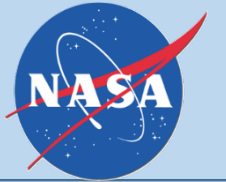
LRL DESCRIPTION: vacuum glovebox



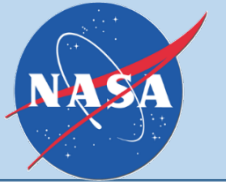
14-15 April 2010



LRL DESCRIPTION: vacuum glovebox



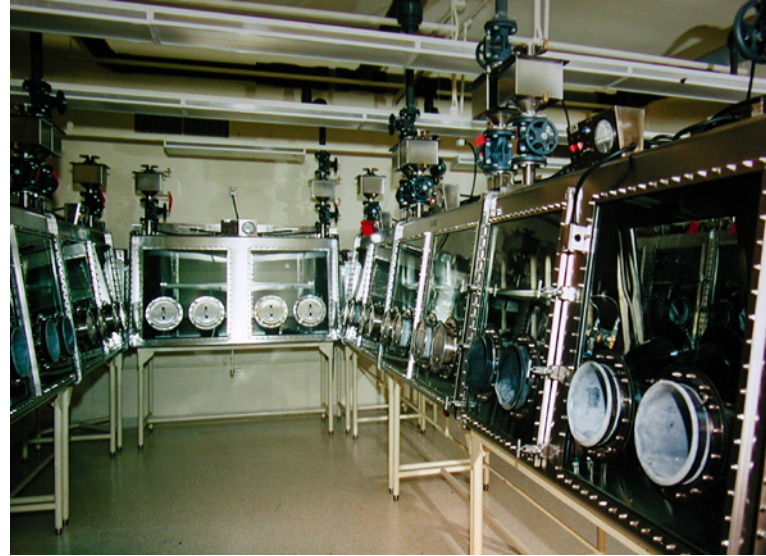
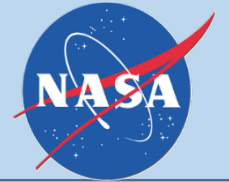
LRL DESCRIPTION: vacuum glovebox



Underfloor support for vacuum glovebox: sterilant tanks, vacuum pumps



LRL DESCRIPTION: biological gloveboxes



NASA-S-67-693

BIOLOGICAL CABINETRY

FLORESCENT
LIGHTS

FILTER
THERMOSTAT

FILTER
CANISTER

STERILIZER
CONTROLS

STEAM
STERILIZER

HINGED
VIEWING
PANELS

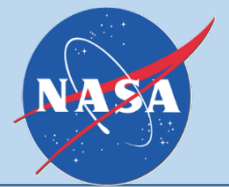
GLOVE
PORTS

FREEZER

SINK

DECON BATH

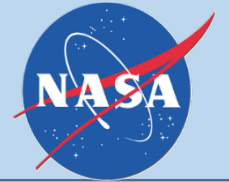
DEBATES: Technical tension between containment & cleanliness



Negative pressure containment did not protect sample purity from terrestrial contaminants
Abundance of biological sterilants in the laboratory environment threatened sample pristinity
Vacuum glovebox system leakage introduced laboratory contaminants (vacuum glovebox was made more reliable after a few years, but by then positive pressure nitrogen gloveboxes were preferred)

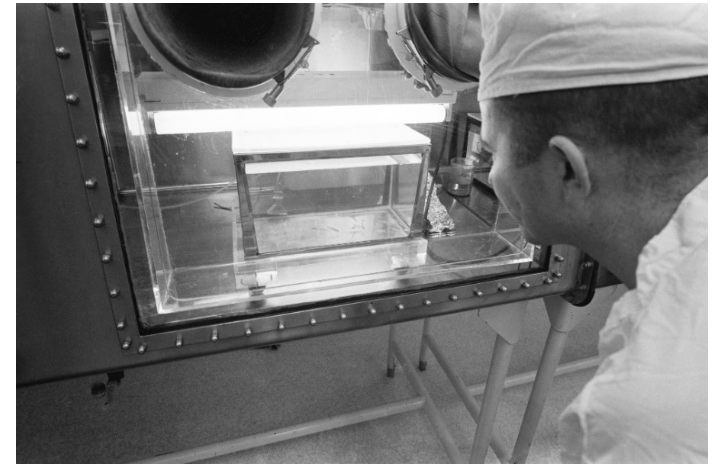


OTHER DEBATES – how samples are used

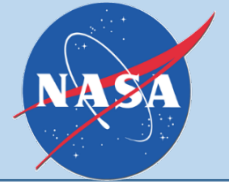


- Debate between biohazard detection and planetary science - portion of samples required for biohazard testing:

Portions of some samples, including samples from core tubes to obtain subsurface material shielded from radiation, were allocated for quarantine testing. A total of 2.259 kg from all missions, less than 1%, was allocated for quarantine testing and the follow-up biological measurements for Apollo 15, 16 and 17 samples.



OTHER DEBATES – how samples are used



List of sample laboratories within the LRL (behind the bio barrier):

Vacuum system

Gas Analysis Lab

Physical-Chemical Test Lab

Spectrographic lab

Radiation Counting Lab

Bio-prep Lab

Bio-analysis Lab

Holding lab for germ-free mice

Holding lab for conventional mice

Lunar Microbiology Lab

Bird, fish, invertebrate lab

Microbiology lab

Egg and tissue culture lab

Plant lab for germ-free algae, spores, seeds

Other labs behind the LRL bio-barrier:

Crew virology lab

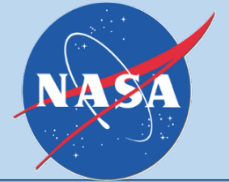
Bio-safety lab

Bio-medical lab

The rules have changed! Planetary Protection now includes both hazard detection and life detection at the molecular level. Different facilities and protocols are required – probably cleaner ones requiring less sample.



OTHER DEBATES – how samples are used

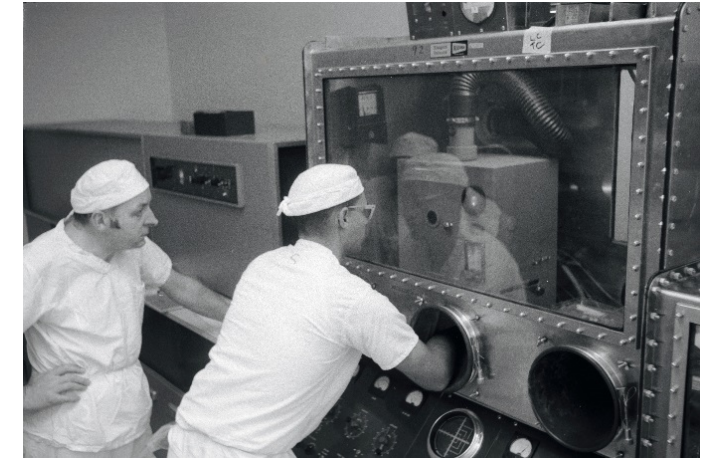


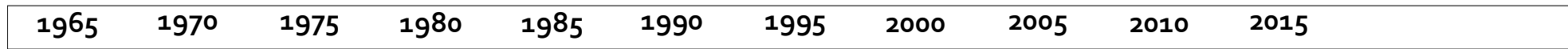
What is the appropriate depth of preliminary examination of samples?

For the Apollo samples, the Preliminary Examination Team (PET) was charged with describing the samples so they could be appropriately allocated for research. They worked inside the LRL, viewing specimens in gloveboxes. Instruments provided inside the bio-barrier included an emission spectrograph for elemental composition, gas mass spectrometer for noble gases, radiation counting lab for short-lived species, and optical microscopes for basic characterization.

The Lunar Sample Analysis Planning Team (LSAPT) was charged with responding to sample requests from outside investigators by determining appropriate sample and making allocation recommendations. LSAPT worked outside the LRL, meeting frequently with the PET to gather information about the samples.

ISSUE: Maintain fair access to the science rewards resulting from sample study. PET was not allowed to scoop the best science because of access to the samples.





New Facility Planning, Construction, Check-out

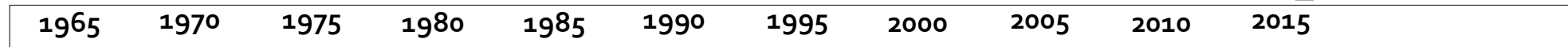
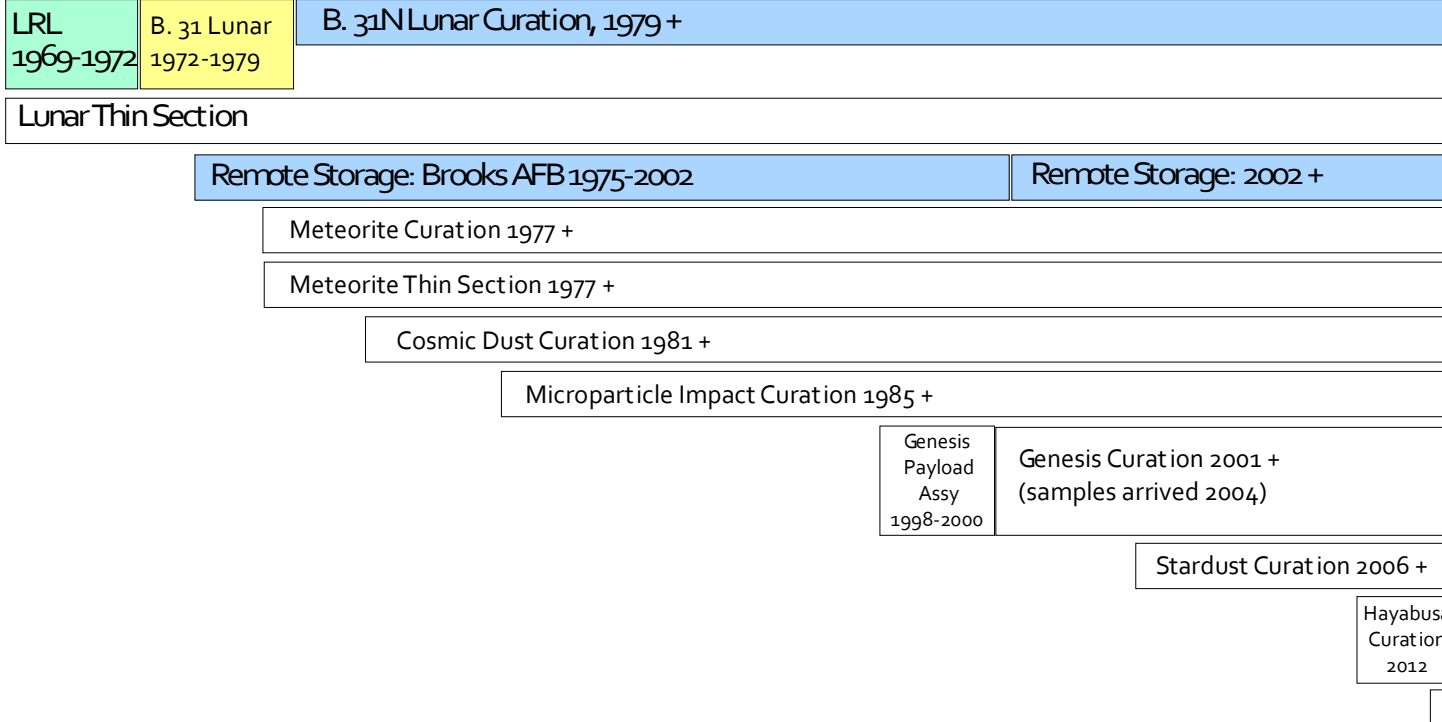
LRL
1964-1968

B. 31N
1972-1979

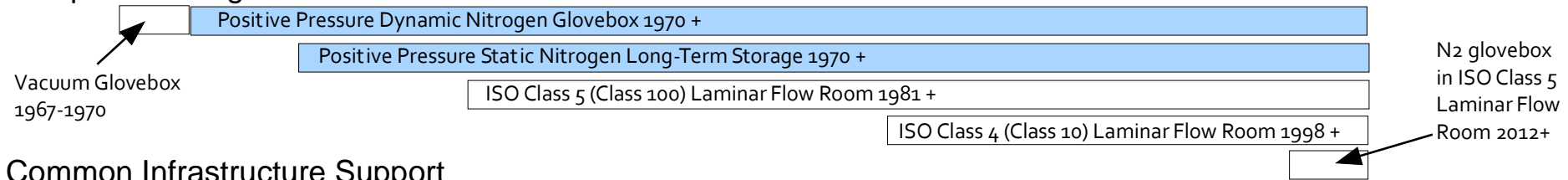
Retro-fit facilities:

B. 31 Lunar Meteorite Cosmic Dust	Microparticle Impact Genesis Stardust	Hayabusa O-REx
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Sample Handling & Curation Facility Operation



Sample Handling Environment



Common Infrastructure Support



LUNAR CURATORIAL FACILITY DESCRIPTION



1100 m², two floors, \$2-3M

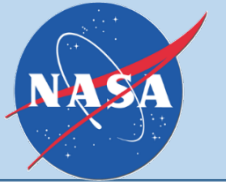
About 8 NASA civil servants and 20 contractors (1980 estimate-not current actual) working one shift

Outside science community recruited to participate in scientific oversight of sample curation/allocation and planning for other astromaterials curation (Lunar and Planetary Sample Team, LAPST, 1978-1993)

Facility focus on

- Physical security
- Protection from natural hazards
- Core location for utilities – air handlers, nitrogen gas
- Rigorous screening of construction and equipment material composition

LUNAR CURATORIAL FACILITY DESCRIPTION



http://curator.jsc.nasa.gov/lunar/laboratory_tour.cfm

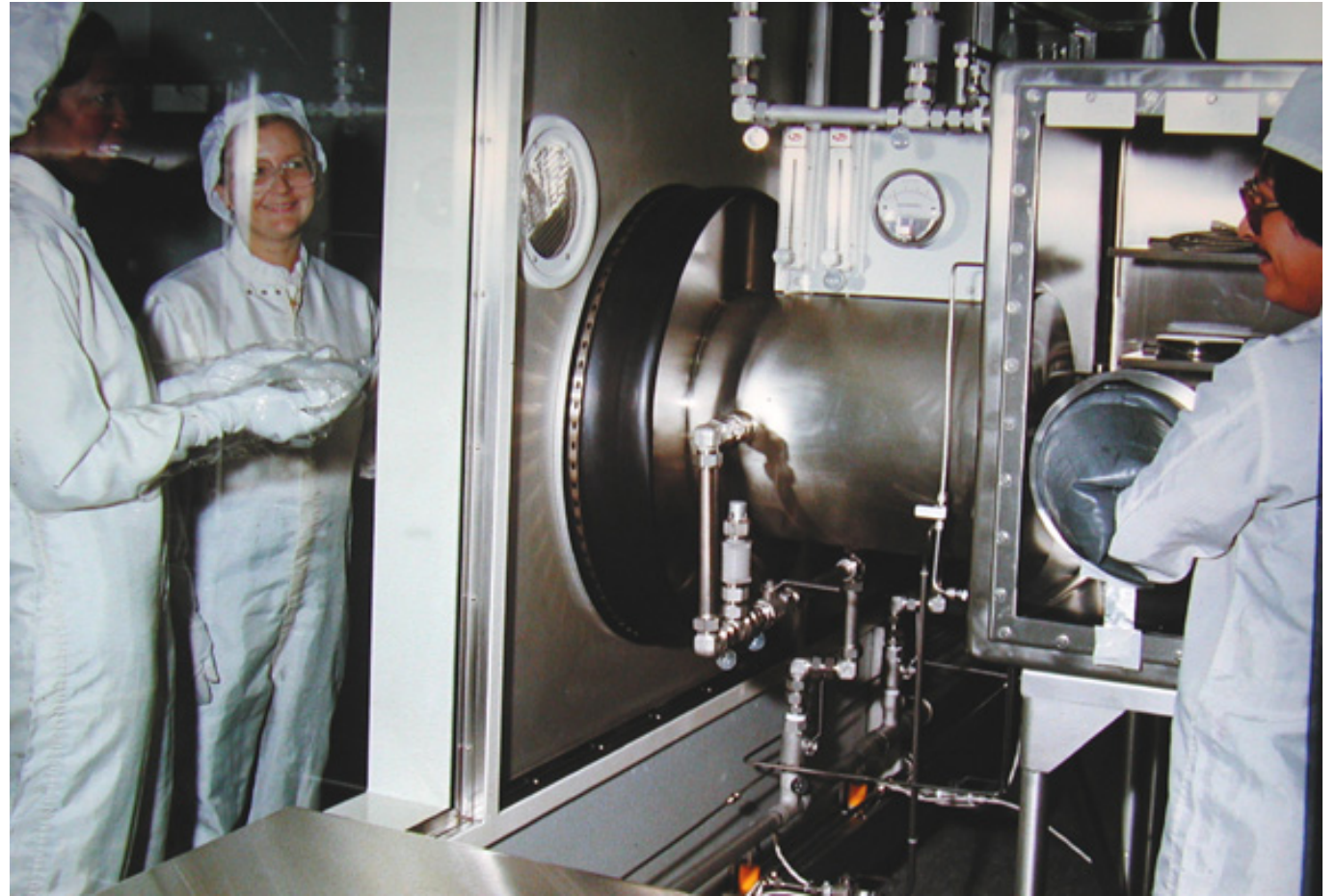
PRISTINE CORRIDOR & VAULT

PRISTINE SAMPLE LAB

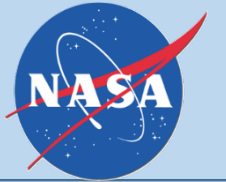
RETURNED SAMPLE VAULT

EXPERIMENT LAB

CORE & SAW ROOM



LUNAR CURATORIAL FACILITY DESCRIPTION



http://curator.jsc.nasa.gov/lunar/laboratory_tour.cfm

PRISTINE CORRIDOR & VAULT

PRISTINE SAMPLE LAB

RETURNED SAMPLE VAULT

EXPERIMENT LAB

CORE & SAW ROOM

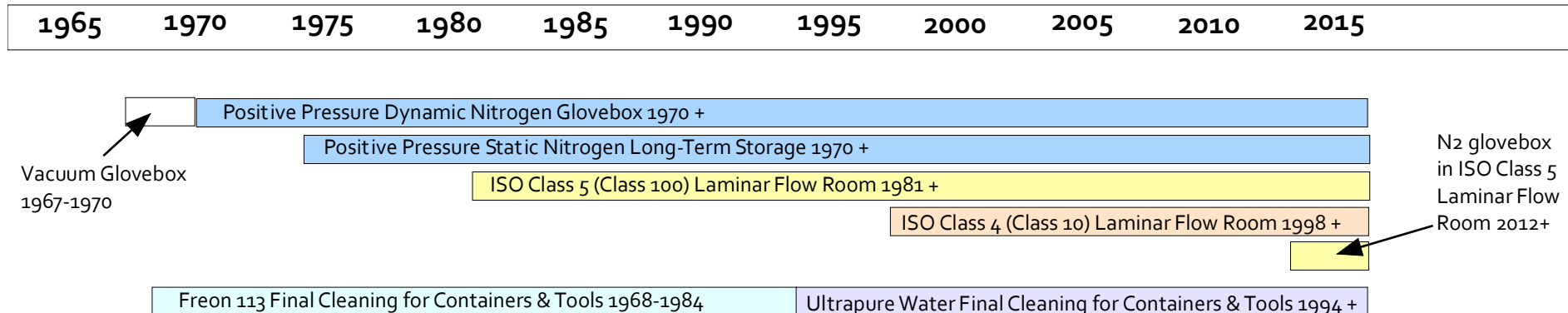


LUNAR CURATORIAL FACILITY: Material screening

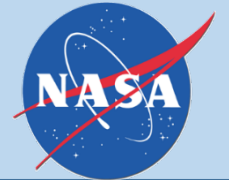


All materials used in constructing and equipping the building (including floor coverings, walls, plumbing, light fixtures, and paint) were carefully screened to exclude chemical elements that would pose unacceptable contamination threats to the lunar samples.

Materials allowed into the laboratory and into the gloveboxes are constrained to a few, simple composition of acceptable chemical elements, non-shedding and easily cleanable with UPW.

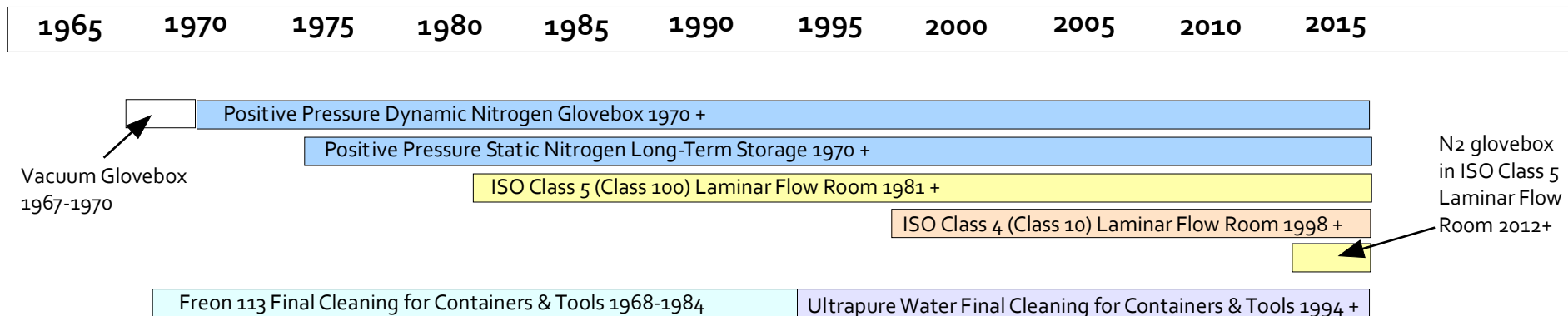


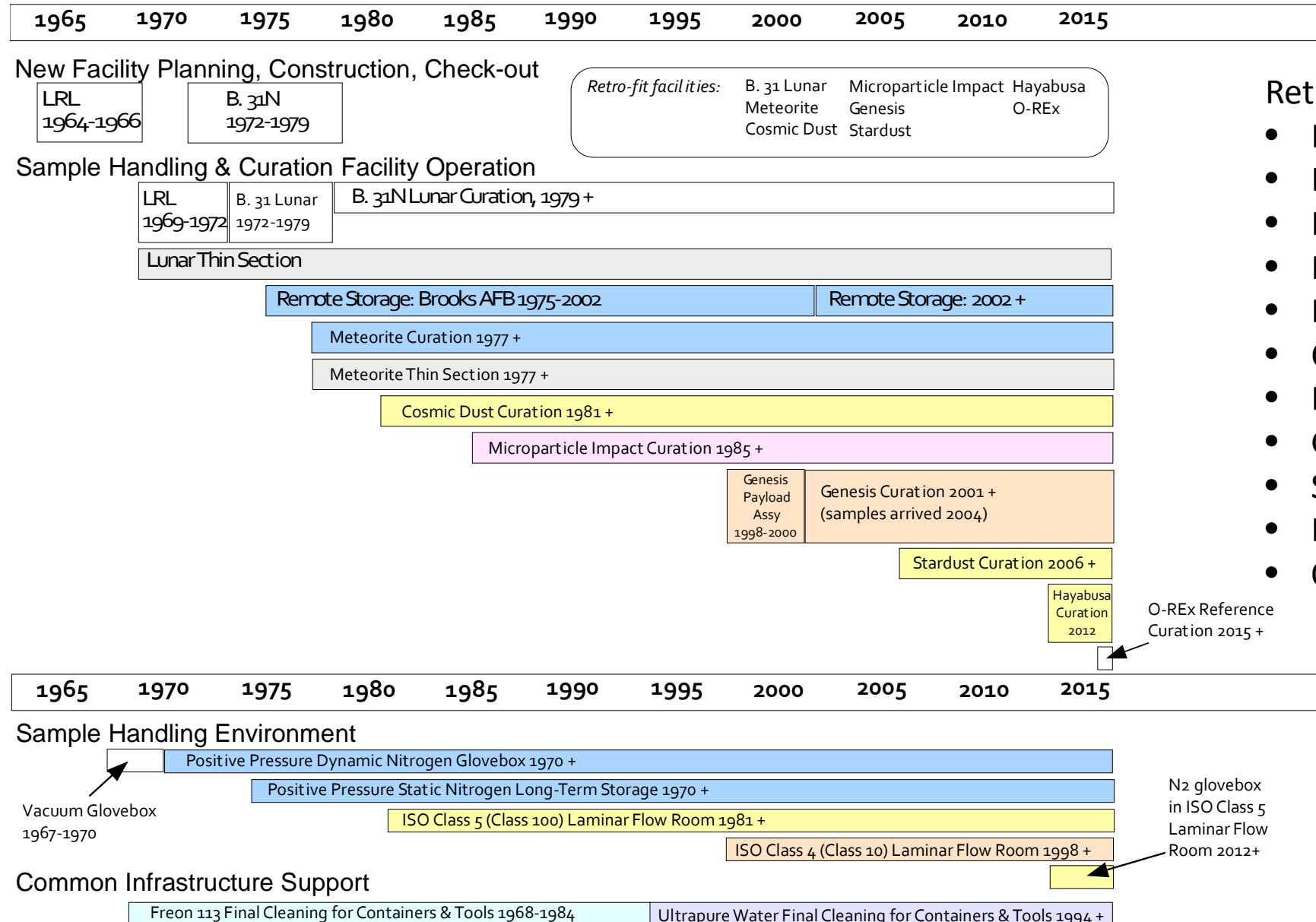
ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space



- **Faster**
 - Eliminates lengthy review period
 - Restricted focus
 - Modification is faster than whole construction
- **Less expensive**
 - Less formal review process
 - Takes advantage of existing structure
 - Takes advantage of existing utilities, shared resources
 - Multiple, smaller contracts for construction, certification

- **May not achieve optimum layout for long-term curation**
 - Equipment maintenance and upgrade may be more costly or difficult

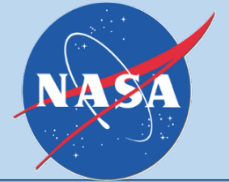




Retrofitted lab spaces:

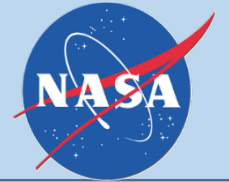
- B. 31 Lunar Curation temporary
- Lunar thin section
- Remote storage
- Meteorite curation
- Meteorite thin section
- Cosmic Dust Curation
- Microparticle Impact Curation
- Genesis Curation
- Stardust Curation
- Hayabusa I Curation
- O-Rex Reference Materials

ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space



ROCKS - METEORITES

ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space

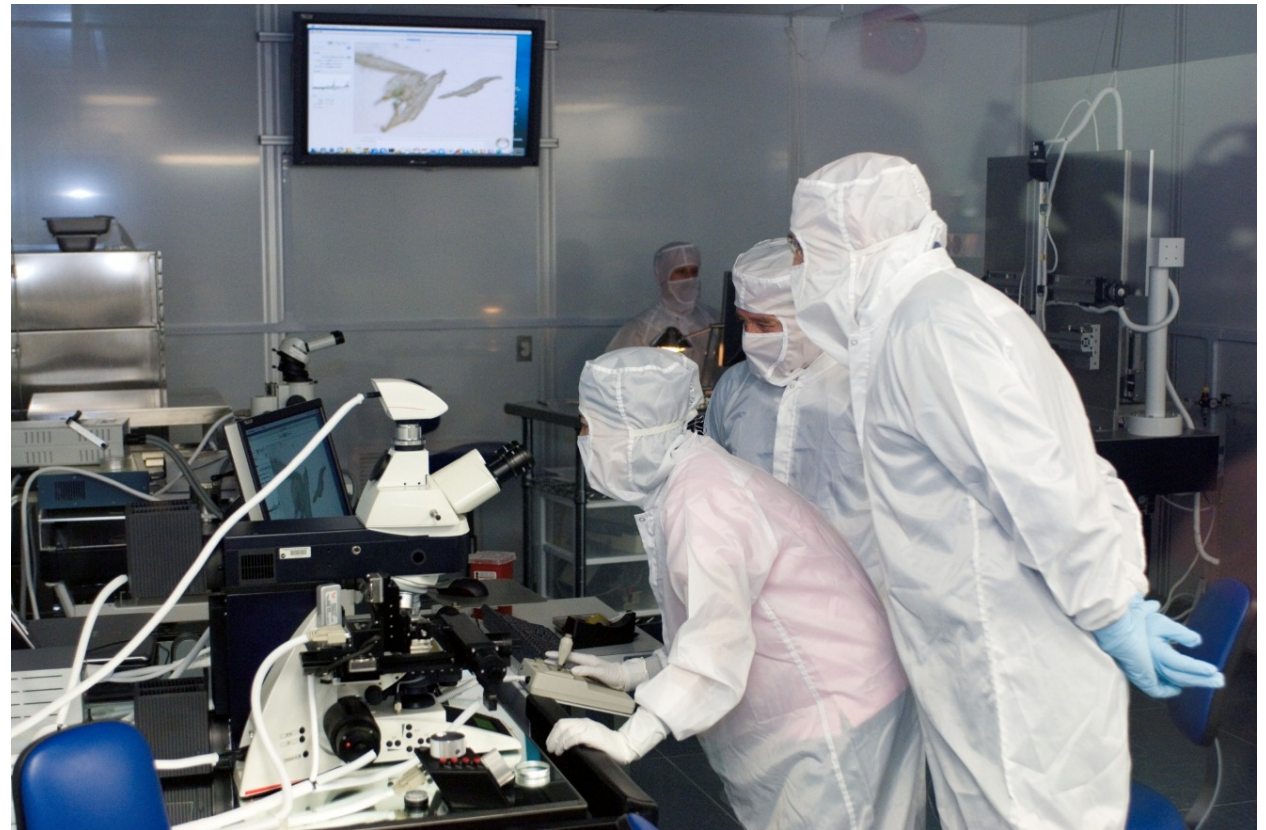


Cosmic Dust particles removed from silicone oil



14-15 April 2016

Stardust particles in aerogel

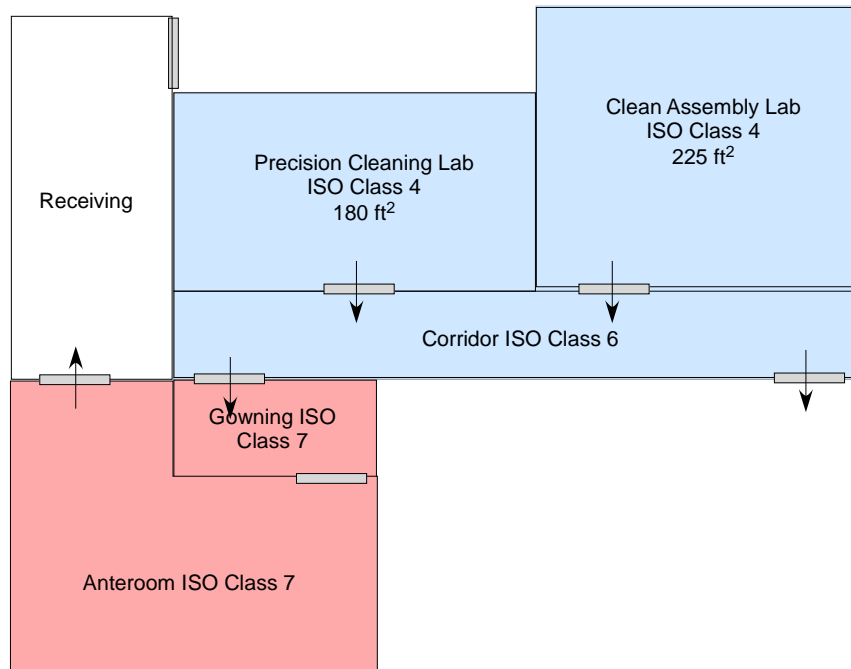
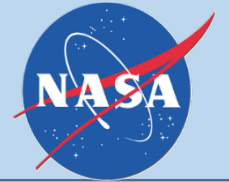


SMALL PARTICLES

EURO-CARES WP3

24

FACILITY FOCUS: ISO Class 4, a drop-in room



SHOWN IN BLUE

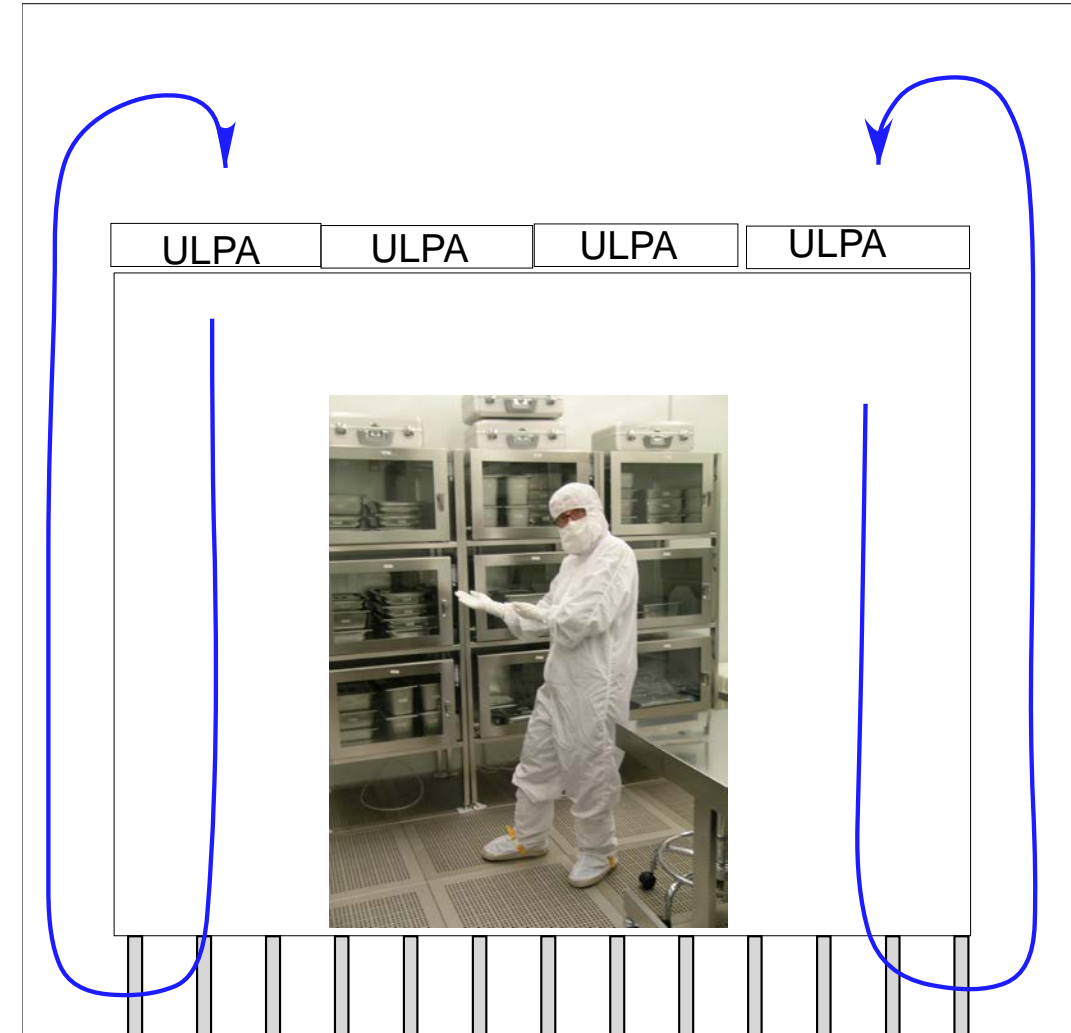
Vertical laminar flow

100 fpm ULPA (<0.12 μ)

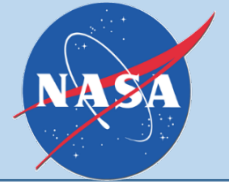
Fed by HEPA air handler (<0.3 μ)

Total ULPA coverage ceiling

Total floor air flow holes



ADDING ASTROMATERIAL CURATION LABORATORIES: Retrofitting lab space

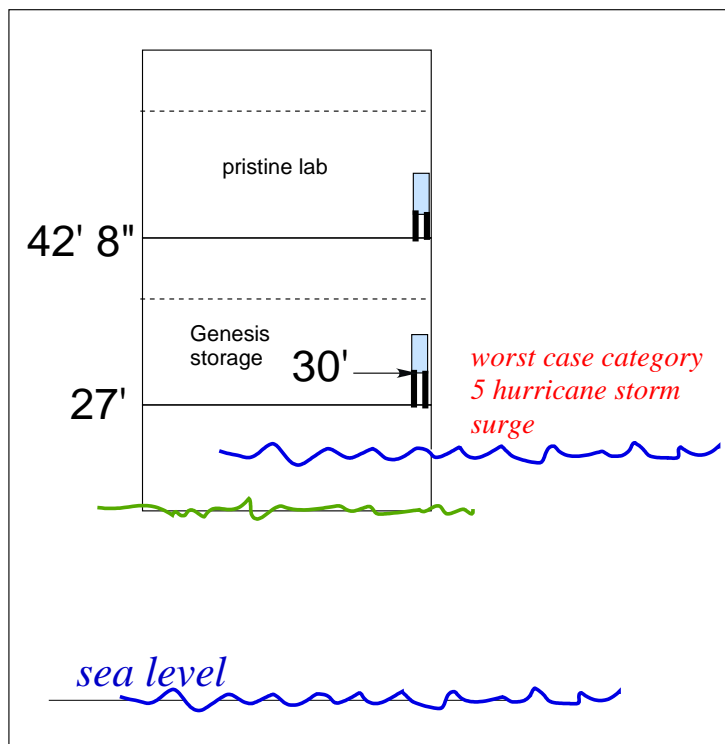
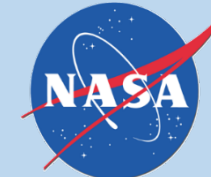


ATOMS – SOLAR WIND

Genesis
Clean Assembly for flight
Characterize and clean fragments



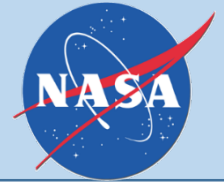
FACILITY FOCUS: Hurricane readiness storage



Samples not currently being worked are stored in upstairs vault during hurricane season. Kept in rolling desiccators purged with nitrogen. Moving process practiced annually.



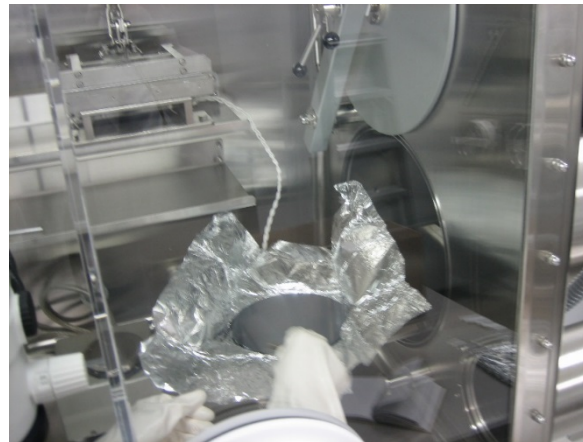
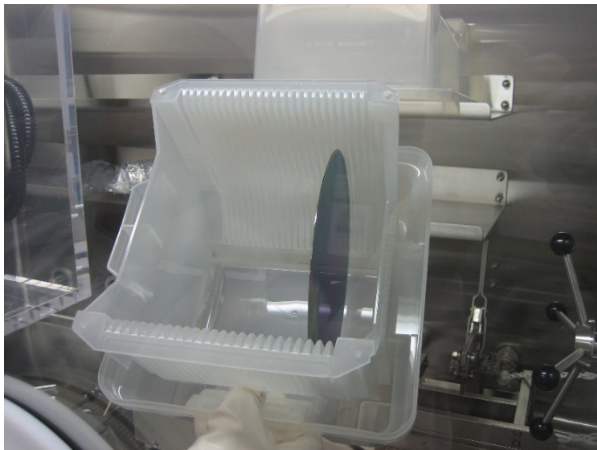
PARTICULATE VS ORGANIC CLEANLINESS: Technical tension



Room air particulate cleanliness achieved by continual filtration using HEPA, ULPA filters. Clean air sweeps away airborne particles. These devices are typically constructed using RTV sealant, which offgases siloxanes and other airborne molecular species.

Cleanest air is achieved with controlled unidirectional flow.

Organic cleanliness for small work areas, like gloveboxes or robotic enclosures, may be achieved by use of clean cover gas, e.g., point-of-use purification and filtration of nitrogen.

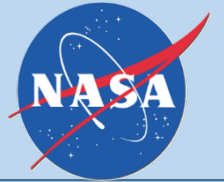


Parameter	RL	Sample Identification / Site	
30 Elements on 200mm or smaller Bare Wafers by VPD			
Wafer Size: 200mm			
		COLD GLOVE BOX	CONTROL
Units: 1E10 atoms/cm2			
Aluminum (Al)	0.05	81	*
Antimony (Sb)	0.005	*	*
Barium (Ba)	0.001	*	*
Beryllium (Be)	0.3	0.5	*
Cadmium (Cd)	0.003	*	*
Calcium (Ca)	0.1	0.6	0.4
Cerium (Ce)	0.001	*	*
Chromium (Cr)	0.01	1.3	*
Cobalt (Co)	0.005	*	*
Copper (Cu)	0.01	*	*
Gallium (Ga)	0.005	*	*
Indium (In)	0.001	*	*
Iron (Fe)	0.05	5.3	0.74
Lithium (Li)	0.05	*	*
Magnesium (Mg)	0.05	2.7	0.59
Manganese (Mn)	0.01	0.16	0.01
Molybdenum (Mo)	0.005	0.085	*
Nickel (Ni)	0.05	0.97	*
Potassium (K)	0.05	0.41	0.50
Rubidium (Rb)	0.05	*	*
Sodium (Na)	0.05	2.1	0.15
Strontium (Sr)	0.002	*	*
Thorium (Th)	0.001	*	*
Tin (Sn)	0.005	0.042	0.007
Titanium (Ti)	0.05	0.15	0.06
Uranium (U)	0.001	*	*
Vanadium (V)	0.01	*	*
Yttrium (Y)	0.002	*	*
Zinc (Zn)	0.05	*	*
Zirconium (Zr)	0.005	*	*

* = Analysis revealed that the analyte was not found at or above the reporting limit. RL = Reporting Limit

Report Notes: Witness wafer exposed for 24 hours, 5/13-14/08.

LUNAR CURATION FACILITY: is almost 40 years old!



And looks like new!

It was well planned for Apollo sample
curation requirements!

Carefully executed!

Can accept upgrades and served Apollo
collection well!

